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(54) **Method and apparatus for tracking objects in a target area of a moving organ**

Verfahren und Vorrichtung zum Nachverfolgen von Objekten in einem Zielbereich eines sich bewegenden Organs

Procédé et appareil de suivi d'objets dans une zone cible d'un organe en mouvement

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Description

FIELD OF THE INVENTION

[0001] The invention relates to the technical field of medical imaging, particularly in Percutaneous Interventions such as Transcatheter Aortic Valve Implantation (TAVI) procedures.

STATE OF THE ART

[0002] The trend of minimal invasiveness has increased the importance of imaging in clinical interventions. Due to the small incisions made for the interventions, clinicians can no longer use direct visual inspect to navigate their tools, and instead have to rely on intra-procedural images generated from real-time imaging modalities such as X-ray fluoroscopy, ultrasound echography and intra-procedural magnetic resonance imaging.

[0003] Image guided navigation driven by visual inspection of the intra-procedural images inherently suffers from limited accuracy and operator bias due to the subjective evaluation by the operator. This effect is more prominent when navigating in moving areas, such as the thoracic region. Furthermore, the intra-procedural images generated by the real-time imaging modalities typically have reduced image quality, and may not always reveal anatomical structures relevant for the clinical procedure. Contrast liquid can be used to visualize the anatomical structures. However, intra-procedural administration of contrast liquid should be limited to prevent patient harm.

[0004] Employing an automatic feature tracking mechanism can provide a solution for these issues. Such a mechanism can provide quantitative information about the position of the interventional tools, and their target location. Using this quantitative information during navigation can eliminate the operator bias, and potentially increase the positioning accuracy. Moreover, quantitative information about the position of image features can be used as a reference point to fuse other images, optionally acquired using different imaging modalities as disclosed, for example, in A. Guéziec et al., "Anatomy-based registration of CT-scan and intraoperative X-ray images for guiding a surgical robot", IEEE Transactions on Medical Imaging (1998) or US patent No 7,778,688.

[0005] A typical tracking process is initialized by indicating the initial position of the feature that is to be tracked. This can either be done automatically, or manually by the user. After this, a prediction on the future position of the feature is made. This prediction is based on a dynamical model describing the expected motion of the feature. By measuring the actual position of the feature, the predicted position is then updated together with the model parameters as disclosed, for example, in the paper by M. Isard and A. Blake, "Condensation - conditional density propagation for visual tracking", International Journal of Computer Vision (1998) or in US patent No 8,223,207. This process is repeated by making a new prediction on the next time step, and is continued until the tracking process is stopped.

[0006] When the tracked feature is obscured, the tracking process can be continued by generating new predictions on the feature position for future time steps. However, no measurements can be performed, meaning that no corrections can be made to these predictions. Due to the inevitable differences between the predicted motion and the actual motion, modelling errors will stack, and the predicted feature position will diverge from the true position. Furthermore, the actual motion may be different from the predicted motion due to physiological reaction of the body in response of the insertion of an interventional tool. Consequently, when the feature is obscured, these tracking mechanisms can only provide an accurate position of the tracked object for a limited time.

[0007] US patent application published with number 2011/0033094 discloses a method for navigating a therapeutic device to a location by continuing to give an estimated position of the device target location, despite being unable to visually identify this area in intra-procedural X-ray fluoroscopy images. This is achieved by tracking a feature, which is visible during X-ray fluoroscopy, in the vicinity of the device target location assuming it experiences the same motion as the device target location. As a result, the geometric relation between the tracked feature and the device target location remains constant under all circumstances. By establishing this geometric relation in a pre-procedural image, the device target location can be derived in the intra-procedural from the position of the tracked feature during X-ray fluoroscopy.

[0008] US patent application published with number 2005/096543 describes techniques for tracking moving regions of interest in medical imaging, wherein images are acquired i.a. by ultrasounds or X rays and the velocity of said moving regions can be estimated i.a. at a location relative to the region of interest.

[0009] European patent application published with number EP 2 434 454 A2 considers relative position of features only for indirectly determining their position at a given moment. Motion modelling is performed globally, i.e. for the whole heart.

[0010] In case of trans-catheter heart valve placement, the aortic annulus is the target location, and is invisible without administration of contrast liquid in intra-procedural X-ray images, while the tracked feature can be any anatomic or artificial object which is distinguishable during X-ray fluoroscopy and has the same motion pattern as the aortic root, typically a calcified area near the valves or a stent or any other deployed device.

[0011] Using these tracking mechanisms to guide interventional tools to a certain location can, however, pose problems if the tracked feature resides near the target location of the tool. If the tool approaches its target location, the presence of the tool can, in fact, deform or occlude the tracked feature, preventing an accurate localization by the tracking mechanism.

[0012] Tracking such feature during intervention is, in fact, not easy to achieve. As long as the therapeutic device approaches the target location, the annulus, and thus the calcifications, will response to the presence of the therapeutic device. Particularly, the calcifications tend to deform thus not only bringing the tracking algorithm likely to fail but also, and above all, modifying the geometric relation which is used to reconstruct the target location with a consequent reduction of accuracy which may be crucial for the success of the intervention. If another feature is used instead of calcification spots, this is subjected to the same problems, even increased because stent or any other metallic device tends to move with a different motion as the motion of the target location. Especially if a stent is selected distal to the coronary ostia, the motion of this stent will be significantly different to the motion of the target location.

[0013] There's thus the need to improve the tracking process to avoid positioning errors which may be crucial for the success of the intervention.

SUMMARY OF THE INVENTION

[0014] It is thus an object of the present invention to provide an improved method for tracking objects in a target area of a moving organ, particularly for use in minimally invasive interventions.

[0015] The invention reaches the aim with a method for tracking objects in a target area of a moving organ from sequences of consecutive image frames of such organ, which images are timely separated by a certain time interval, the method comprising the following steps:

a) identifying, in at least a reference image of a sequence, at least a first feature, and at least a second feature which are typically subject to synchronized periodic motion. The first feature can be the target area itself or any feature that experiences the same motion as the target area such as, for example, a calcified spot;

b) tracking the position of such first and second features in other images of the same or another sequence in order to learn motion patterns of such features;

c) determining a dynamic geometric relation between such first and second feature. Such relation is typically a distance, but any type of relation can be used for the purpose;

d) determining the position of the first feature in the same or different image frames of the same or different image sequence by using the position of the second feature and the dynamic geometric relation as determined in step c) when such first feature is not visible.

[0016] The invention employs the property of synchronized periodic motion to establish the dynamic geometric relationship between the positions of the tracked features. This makes the invention generally applicable for all situations where periodic motion is involved, without assuming any specific global motion model. The inventors realized this by learning the periodic motion of the individual features. When one of the features is obscured, knowledge about the periodic motion patterns of both features, the position of one of the features, and the phase of the periodic motion can be used to derive the position of the obscured feature.

[0017] If the first feature is the device target location itself, such location is immediately determined. If the first feature is not the target location, but a feature that experiences the same motion as the target location, the position of the device target location can be derived from the position of the first feature by using the geometric relation between the first feature and the target area, which is typically determined in a pre-procedural image as taught, for example, in US patent application published with number 2011/0033094.

[0018] In the case of a TAVI procedure, the device target location is visualized in an aortogram. This requires injection of a contrast agent, since the aortic root contours are hardly visible without contrast agents. The first feature can be any object residing in, or close to the aortic annulus, such as a deployed device, or a calcified area. The second feature is not generally located in the aortic annulus. It can be, for example, a deployed device in the vicinity of the first feature or any other object which does not experience the same motion as the first feature.

[0019] Motion patterns of the features, to be used for determining dynamic relation of the same, are typically extracted from the average motion of the features over tracked periods. Period boundaries are determined, for example, with automatic auto-regression methods and/or manual annotation and/or using external input signals, such as ECG, blood pressure, or similar. These external input signals can also be employed to aid the tracking process in general by providing quantitative feedback on the phase of the periodic motion.

[0020] One example of determining a dynamic geometric relation is computing the difference between motion patterns of the features for all or some of the phases in the periodic motion cycle, and mapping these geometric relations to the corresponding phase. Through interpolation of the mapped set of learned geometric relations, the geometric relations for all phases of the periodic motion cycle can be derived.

[0021] When a multitude of image sequences is used to establish the geometric relations between the features and the device target location, all image sequences are preferably acquired under the same geometric conditions. In the case of 2-dimensional X-ray imaging, identical projection angles can be used. Using a biplane X-ray setup to establish 3-dimensional geometric relations between the tracked features and the target area, allows different X-ray projections during the method. Alternatively, different imaging modalities can be used to determine the geometric relation of the first feature to the target area, such as CT, MRI or Ultrasound. This reduces the number of acquisitions necessary and thus patient exposure to radiation and contrast agent.

[0022] More than two features can be identified. In this case, the first feature still experiences the same motion as the target area. The other tracked features can be subject to any periodic motion pattern, as long as this motion is synchronized with the target area. By tracking a multitude of features, the probability that all features are simultaneously obscured is decreased, increasing the overall robustness of the method.

[0023] The invention also relates to a computer product directly loadable into the memory of a computer and comprising software code portions for performing the method as disclosed above when the product is run on a computer.

[0024] According to another aspect, the invention relates to a monoplane, biplane or rotation angiographic X-ray apparatus for acquiring two-dimensional images. The apparatus comprises means for obtaining a cine of consecutive image frames of the aortic root of a patient and processing means programmed for performing the method according to the invention to track one or more features of a target area of the aortic root of the patient, for example to navigate a stent or a valve.

[0025] The apparatus is advantageously adapted to capture fluoroscopy images and aortograms. Aortograms are mainly used to determine the device target location and its geometric relation to one of the tracked features, while fluoroscopy images are mainly used for determining the position of all tracked features and their internal geometric relations.

[0026] Further improvements of the invention will form the subject of the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The characteristics of the invention and the advantages derived therefrom will be more apparent from the following description of non-limiting embodiments, illustrated in the annexed drawings, in which:

Fig. 1 is a flowchart of the invention main steps in a preferred embodiment;

Fig. 2-4 show a schematic illustration of an aortic root (up) and a deployed instrument in the vicinity (below) with a circle indicating the position of two features to be tracked: during the learning phase all features are tracked to learn their periodic motion pattern as shown in the right part of figure 2; the geometric relation between the features as a function of the phase as obtained from the individual feature motion patterns is shown in fig. 3 while Fig. 4 shows how, if a feature is obscured, its position can be derived from the position of a different feature using the learnt periodic distance function and the current phase of the periodic motion.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0028] The invention is particularly advantageous in image guidance during minimally invasive cardiovascular interventions based on 2D angiographic film of X-ray images and it will be mainly disclosed with reference to this field. Examples of such interventions are percutaneous coronary interventions (PCI) and percutaneous aortic valve replacement (PAVR).

[0029] Examples of trackable features for these interventions include anatomical structures, interventional tools, and deployed devices. Such features are typically subject to periodical motion originating from the heart beat. Because the motion of both features is governed by the same source, the phase of the motion is synchronized at all time. Due to the complex non-linear deformations of the heart, no simple global motion model such as affine of rigid motion will be able to accurately describe the deformation of the heart. Moreover, because the second tracked feature should remain visible at all times, it should reside at a significant distance from the feature of interest. As the distance between the features increases, the errors of these simplified motion models will also increase. Learning the periodic motion patterns of all tracked features separately, provides a method to overcome the need for complex motion modelling.

[0030] The flow of the invention can conceptually be split in two distinct phases: a learning phase and a tracking phase. During the learning phase, the periodic motion patterns of both features are analysed and learnt to establish the relation between both features. During the tracking phase, the learnt motion patterns are used to derive the position of obscured features, as long as one other feature remains visible. Any frequency change in motion, for example due to physiological reaction of the body in response of the insertion of an interventional tool, will have no influence on the tracking accuracy since its motion pattern relationship is known.

[0031] Despite the conceptual separation of the learning phase and the tracking phase, behaviour from both phases can be combined into a single adaptive tracking method. This allows the method to adapt to small changes in the learned motion patterns.

[0032] With reference to the flowchart diagram of Fig. 1, the steps of one embodiment of the invention are now described.

Step 1: Define positions of multiple features subject to synchronized periodic motion

[0033] To initialise the tracking process, the initial positions of the tracked features should be defined. These positions should be defined in an image that is part of an image sequence, such that the features can be tracked through the sequence. This sequence can either be a real-time image stream, or a prerecorded image sequence.

[0034] The positions can be defined by the user, for example by pointing out the position of the features in the image, or by drawing a region of interest around the feature. Alternatively, if the visual characteristics of the feature are already known, the system can automatically detect the initial position of the feature.

[0035] Once the positions of the features are known, the system can acquire templates that capture the visual characteristics of the features. These templates can be used to recognize the features in other frames of the images sequence.

Step 2: Learn periodic motion patterns of all features

[0036] Having initialised the feature positions, the features can be tracked over time through the image sequence. A tracking mechanism typically has a dynamical models describing the expected motion of the features. However, since no information is known about the expected motion, a naive model is typically used during this phase.

[0037] When the features have been tracked for a sufficient time, a representative periodic motion pattern is derived for each feature. One example method for constructing such a pattern is by computing the average motion of the features over all tracked periods. To accomplish this, the period boundaries should be known. Some examples of finding these bounds are: automatic autoregression methods, manual annotation by the user, and external input signals such as ECG for cardiac motion.

[0038] Once the motion patterns for all features are known, dynamic geometric relations between all feature combinations are defined. Computing the difference between the motion templates of two features yields a periodic function that describes geometric relation between two features for all phases in the periodic motion cycle. This periodic function can, for example, be implemented by a lookup table, mapping the phase to the relative motion between features.

[0039] When the geometric relations between the feature combinations are defined, the learning phase is completed and the tracking phase can be started.

Step 3: Detect obscuration of features during tracking

[0040] During the tracking phase, the tracking is either performed in the same image sequence as used in the learning phase, or a different image sequence. For the tracking phase, this typically is a real-time image feed. In any case, the geometric relations between the tracked features should be known.

[0041] The periodic motion patterns acquired in the learning phase can be used to predict the motion of the features. Additionally, information about the frequency and phase of the periodic motion is added to the state of the model as taught, for example, by J. McNames and M. Aboy, "Cardiovascular Signal Decomposition and Estimation with the Extended Kalman Smoother". Proceeding of IEEE (2006).

[0042] Deviations from the expected motion of the features can indicate feature obscuration. Additionally, different methods exist to automatically detect partial or full obscuration of tracked objects such as those dosclosed in S. Kwak et al., "Learning occlusion with likelihoods for visual tracking", International Conference on Computer Vision (2011). Finally, the user is able to manually indicate when the feature is obscured, and the system should fall back to the indirect tracking mode.

Step 4: Derive position of obscured features using the learnt motion patterns

[0043] When feature obscuration is detected, indirect feature tracking is used. This method uses the position of a second feature, the phase of the periodic motion, and the dynamic geometric relation between the second feature and the obscured feature. Once the feature obscuration is resolved, the system can return to direct tracking of the feature.

Claims

1. Method for tracking objects in a target area of a moving organ from sequences of consecutive image frames of such organ, which images are timely separated by a certain time interval, the method comprising the following steps:

    a) identifying, in at least a reference image of a sequence, at least a first feature and at least a second feature;
    b) tracking the position of such first and such second feature in other images of the same or another sequence in order to learn motion patterns of such features;
    c) determining a dynamic geometric relation between such first and second feature;
    d) determining the position of the first feature in the same or different image frames of the same or different image sequence by using the position of the second feature and the dynamic geometric relation as determined in step c) when such first feature is not visible.

2. Method according to claim 1, wherein such first and second feature are subject to synchronized periodic motion

3. Method according to claim 1 or 2, wherein the dynamic geometric relation is a distance between the first feature and the second feature.

4. Method according to any preceding claim, wherein the first feature experiences the same motion as the target area.

5. Method according to any preceding claim, wherein the sequence or sequences of images comprise one or more X-ray run, wherein at least one image is captured with contrast material, showing the first feature, and at least one image is captured without contrast material, showing the second feature.

6. Method according to any preceding claim, wherein the organ is the aorta, the first feature being identified in the aortic annulus.

7. Method according to claim 6, wherein the first feature is the destination location for a therapeutic device.

8. Method according to claim 7, wherein the therapeutic device is a stent or a valve.

9. Method according to any preceding claim, wherein the first feature is a deployed device or a calcified area.

10. Method according to any preceding claim, wherein the second feature is a deployed device in the vicinity of the first feature.

11. Method according to any preceding claim, wherein the step of determining motion patterns comprises determining the average motion of the features over tracked periods, period boundaries being determined with automatic auto-regression methods and/or manual annotation and/or using external input signals, such as ECG, blood pressure or the like.

12. Method according to any preceding claim, wherein the step of determining dynamic geometric relation comprises determining the difference between motion patterns of the features for all or some of the phases in the periodic motion cycle.

13. Method according to any preceding claim, wherein more than two features are identified, one of them being rigidly coupled to, and/or moving together with, the target position of a stent or a valve to be navigated to the aortic root, the other features being subject to synchronized periodic motion.

14. Method according to any preceding claim, wherein multiple X-ray projections are used to establish the geometric relations between the features and/or the target location.

15. Method according to any preceding claim, wherein the geometric relations between the features and/or the target location are established using other imaging modalities, such as CT, MRI, Ultrasound or the like.

16. Method according to any preceding claim, **characterized in** comprising a learning phase, wherein the periodic motion patterns of all or part of the features are learnt to determine the geometric relations between the features and/or the target location, and a tracking phase wherein the position of at least a non visible feature is tracked by using the position of at least another feature and the dynamic geometric relation as determined in the learning phase.

17. Method according to claim 16, wherein the learning phase and the tracking phase are combined in a single adaptive phase.

18. A computer product directly loadable into the memory of a digital computer and comprising software code portions for performing the method according to any of the preceding claims when the product is run on a computer.

19. X-ray apparatus for acquiring bi-dimensional images, the apparatus comprising means for obtaining a cine of consecutive image frames of the aortic root of a patient, the apparatus further comprising processing means programmed for performing the method according to claims 1 to 17 to track one or more features of a target area of the aortic root of the patient.

20. Apparatus according to claim 19, **characterized in that** it is adapted to capture fluoroscopy images and aortograms, aortograms being mainly used to determine the position of the first feature, while fluoroscopy images are mainly used for determining the position of the second feature.

Patentansprüche

1. Verfahren zum Nachverfolgen von Objekten in einem Zielbereich eines sich bewegenden Organs aus Sequenzen von aufeinanderfolgenden Bildrahmen eines solchen Organs, wobei die Bilder rechtzeitig um ein bestimmtes Zeitintervall getrennt sind, wobei das Verfahren die folgenden Schritte enthält:

a) Identifizieren, in zumindest einem Referenzbild einer Sequenz, wenigstens ein erstes Merkmal und wenigstens ein zweites Merkmal;
b) Verfolgen der Position solcher ersten und solcher zweiten Merkmal in anderen Bildern der gleichen oder einer anderen Sequenz, damit Bewegungsmustern derartiger Funktionen zu lernen;
c) Bestimmen einer dynamischen geometrichen Beziehung zwischen dieses erste und zweite Merkmal;
d) Bestimmen der Position des ersten Merkmals in dem gleichen oder unterschiedlichen Bildrah-

men aus dem gleichen oder unterschiedlichen Bildsequenz durch Verwendung der Position des zweiten Merkmals und der dynamische geometrische Beziehung wie in Schritt c) bestimmt wenn ein solches erste Merkmal nicht sichtbar ist.

2. Verfahren nach Anspruch 1, wobei dieses erste und zweite Merkmal eine synchronisierte periodische Bewegung unterliegen

3. Verfahren nach Anspruch 1 oder 2, wobei die dynamische geometrische Beziehung einen Abstand ist zwischen dem ersten Merkmal und dem zweiten Merkmal.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei das erste Merkmal die gleiche Bewegung erfährt wie die Zielfläche.

5. Verfahren nach einem der vorhergehenden Ansprüche, worin die Sequenz oder Sequenzen von Bildern einer oder mehreren X-ray Läufe enthält, wobei das erste Merkmal gezeigt wird in mindestens ein Bild mit Kontrastmittel, und das zweite Merkmal wenigstens in ein Bild ohne Kontrastmittel gezeigt wird.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Organ der Aorta is, wobei das erste Merkmal in der Aortenanulus identifiziert ist.

7. Verfahren nach Anspruch 6, wobei das erste Merkmal das Zielort ist für eine therapeutische Vorrichtung.

8. Verfahren nach Anspruch 7, wobei die therapeutische Vorrichtung einen Stent oder ein Ventil ist.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei das erste Merkmal ein Einsatz-Gerät oder ein Verkalkungsbereich ist.

10. Verfahren nach einem der vorhergehenden Ansprüche, wobei das zweite Merkmal ein Einsatz Vorrichtung in der Nähe des ersten Merkmals ist.

11. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt der Bestimmung von Bewegungsmustern das Bestimmen der Durchschnittsbewegung der Eigenschaften über Zeiträume verfolgt, wobei Periodengrenzen definiert werden mit automatischer Autoregressionsverfahren und / oder manuelle Annotation und / oder unter Verwendung von externen Eingangssignalen, wie EKG, Blutdruck oder dergleichen.

12. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt der Ermittlung der dynamischen geometrischen Beziehung das Bestimmen der Differenz zwischen Bewegungsmustern der Merkmale für alle oder enige der Phasen der periodischen Bewegung Zyklus umfasst.

13. Verfahren nach einem der vorhergehenden Ansprüche, wobei mehr als zwei Merkmale identifiziert werden, von denen eine starr mit, und / oder sich zusammen mit, die Zielposition eines Stents oder eines Ventils an der Aortenwurzel navigiert wird, die andere Merkmale zu unterliegen eine synchronisierte periodische Bewegung.

14. Verfahren nach einem der vorhergehenden Ansprüche, wobei mehrere Röntgenprojektionen verwendet werden, um die geometrischen Beziehung zwischen den Merkmalen und / oder der Zielstelle zu schaffen.

15. Verfahren nach einem der vorhergehenden Ansprüche, wobei die geometrischen Beziehungen zwischen den Merkmalen und / oder der Zielposition ermittelbar sind mit anderen bildgebenden Verfahren, wie zum Beispiel CT, MRI, Ultraschall oder dergleichen.

16. Verfahren nach einem der vorhergehenden Ansprüche, das einer Lernphase umfasst, wobei die periodische Bewegung Diagramme aller oder eines Teils der Funktionen erlernt werden, um die geometrischen Beziehungen zwischen den Merkmalen und / oder der Zielposition zu bestimmen, und eine Verfolgungsphase gekennzeichnet wobei die Position von mindestens ein nicht sichtbares Merkmal wird unter Verwendung der Position von zumindest einem weiteren Merkmal auch die dynamische geometrische Beziehung, wie in der Lernphase bestimmt verfolgt.

17. Verfahren nach Anspruch 16, wobei die Lernphase und die Spurverfolgungsphase in einem einzigen adaptiven Phasen vereinigt werden.

18. Ein Computerprodukt, das direkt in den Speicher eines digitalen Computers ladbar ist und Softwarecodeteile zur Durchführung des Verfahrens nach einem der vorhergehenden Ansprüche enthält, wenn das Produkt auf einem Computer läuft.

19. Röntgengerät zur Erfassung von zweidimensionalen Bildern, wobei die Vorrichtung Mittel zum Erhalten einer eine von aufeinanderfolgenden Bildrahmen der Aortawurzel eines Patienten, wobei die Vorrichtung ferner Verarbeitungsmittel zur Durchführung des Verfahrens nach Anspruch 1 bis Anspruch 17 programmiert um eine oder mehrere Eigenschaften von einem Zielbereich der Aortenwurzel des Patienten zu verfolgen.

20. Vorrichtung nach Anspruch 19, **dadurch gekennzeichnet, dass** sie angepasst ist, um Durchleuchtungsbilder und aortograms erfassen aortograms wird hauptsächlich verwendet, um die Position des ersten Merkmals zu bestimmen, während die Durchleuchtungsbilder hauptsächlich zur Bestimmung der Position des zweiten Merkmals verwendet.

Revendications

1. Méthode de suivi d'objets dans une région cible d'un organe mobile depuis des séquences d'images consécutives de cet organe, ces images sont séparées par un intervalle de temps défini, la méthode comprend les étapes suivantes:

a) identification, dans au moins une image de référence d'une séquence, d'au moins une première caractéristique et d'au moins une seconde caractéristique;
b) suivi de la position de cette première et seconde caractéristiques dans d'autres images de la même séquence, ou d'une autre séquence, afin de découvrir les modèles de mouvement de ces caractéristiques;
c) détermination d'une relation géométrique dynamique entre cette première et seconde caractéristiques;
d) détermination de la position de la première caractéristique dans la même image, ou dans d'autres images de la même séquence d'images, ou d'autres séquences d'images, en utilisant la position de la seconde caractéristique et la relation géométrique dynamique telles que déterminées dans l'étape c) lorsque cette première caractéristique n'est pas visible.

2. Méthode selon la revendication n° 1, dans laquelle cette première et seconde caractéristiques sont soumises à un mouvement régulier synchronisé.

3. Méthode selon la revendication n° 1 ou 2, dans laquelle la relation géométrique dynamique est une distance entre la première et la seconde caractéristiques.

4. Méthode selon toute revendication antérieure, dans laquelle la première caractéristique subit le même mouvement que la région cible.

5. Méthode selon toute revendication antérieure, dans laquelle la ou les séquences d'images comprennent un ou plusieurs clichés radiographiques, dans lesquels au moins une image est capturée avec un produit de contraste, montrant la première caractéristique, et au moins une image est capturée sans produit de contraste, montrant la seconde caractéristique.

6. Méthode selon toute revendication antérieure, dans laquelle l'organe est l'aorte, la première caractéristique étant identifiée dans l'anneau aortique.

7. Méthode selon la revendication n° 6, dans laquelle la première caractéristique est l'emplacement de destination pour un dispositif thérapeutique.

8. Méthode selon la revendication n° 7, dans laquelle le dispositif thérapeutique est un stent ou une valve.

9. Méthode selon toute revendication antérieure, dans laquelle la première caractéristique est un dispositif déployé ou une région calcifiée.

10. Méthode selon toute revendication antérieure, dans laquelle la seconde caractéristique est un dispositif déployé à proximité de la première caractéristique.

11. Méthode selon toute revendication antérieure, dans laquelle l'étape de détermination des modèles de mouvement comprend la détermination du mouvement moyen des caractéristiques pendant les périodes de suivi, les limites des périodes étant déterminées par des méthodes de régression automatique et/ou annotation manuelle et/ou à l'aide de signaux d'entrée externes, tels qu'un ECG, la pression artérielle, etc.

12. Méthode selon toute revendication antérieure, dans laquelle l'étape de détermination de la relation géométrique dynamique comprend la détermination de la différence entre les modèles de mouvement des caractéristiques de toutes ou certaines des phases du cycle de mouvement régulier.

13. Méthode selon toute revendication antérieure, dans laquelle plus de deux caractéristiques sont identifiées, l'une d'elles étant couplée de manière rigide à, et/ou se déplaçant avec, la position cible d'un stent ou d'une valve devant atteindre la racine aortique, les autres caractéristiques soumises à un mouvement régulier synchronisé.

14. Méthode selon toute revendication antérieure, dans laquelle plusieurs clichés radiographiques sont utilisés pour établir les relations géométriques entre les caractéristiques et/ou l'emplacement cible.

15. Méthode selon toute revendication antérieure, dans laquelle les relations géométriques entre les caractéristiques et/ou l'emplacement cible sont établies à l'aide d'autres techniques d'imagerie, telles qu'un scanner, une IRM, une échographie, etc.

16. Méthode selon toute revendication antérieure, caractérisée comme comprenant une phase d'apprentissage, dans laquelle les modèles de mouvement périodiques de toutes ou partie des caractéristiques sont appris afin de déterminer les relations géométriques entre les caractéristiques et/ou l'emplacement cible, et une phase de suivi dans laquelle la position d'au moins une caractéristique non visible est suivie au moyen de la position d'au moins une autre caractéristique et de la relation géométrique dynamique, comme déterminée pendant la phase d'apprentissage.

17. Méthode selon la revendication n° 16, dans laquelle la phase d'apprentissage et la phase de suivi sont combinées en une seule phase d'adaptation.

18. Un produit informatique pouvant être directement téléchargé dans la mémoire d'un ordinateur numérique et comprenant des portions de code logiciel pour exécuter la méthode conformément à l'une quelconque des revendications précédentes lorsque le produit est exécuté sur un ordinateur.

19. Appareil de radiologie pour l'acquisition d'images bidimensionnelles, l'appareil étant équipé de moyens permettant d'obtenir des images cinématographiques ou consécutives de la racine aortique d'un patient, l'appareil étant également équipé de moyens de traitement programmés pour exécuter la méthode selon les revendications n° 1 à 17 afin de suivre une ou plusieurs caractéristiques d'une région cible de la racine aortique du patient.

20. Appareil selon la revendication n° 19, **caractérisé en ce qu'**il est adapté à la capture d'images de fluoroscopie et d'aortogrammes ; les aortogrammes étant principalement utilisés pour déterminer la position de la première caractéristique, tandis que les images de fluoroscopie sont principalement utilisées pour déterminer la position de la seconde caractéristique.

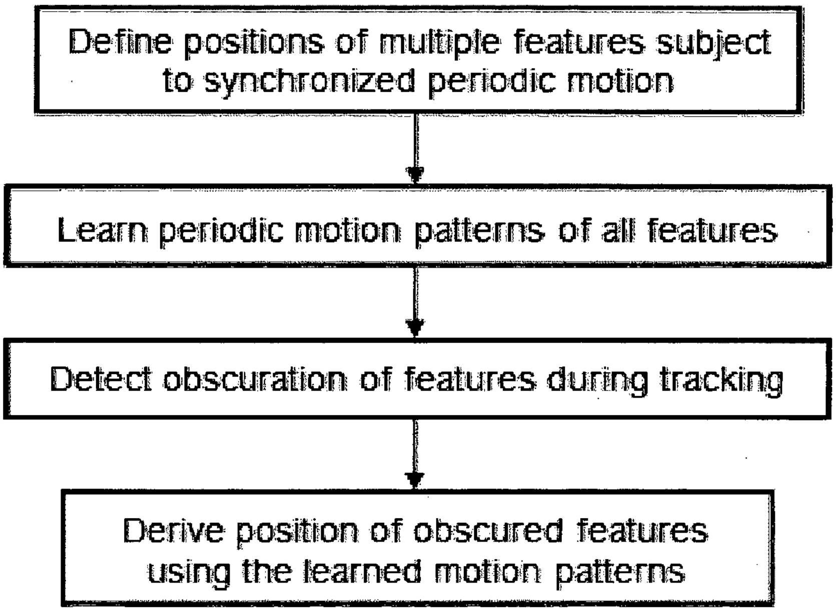
Define positions of multiple features subject to synchronized periodic motion
Learn periodic motion patterns of all features
Detect obscuration of features during tracking
Derive position of obscured features using the learned motion patterns

Fig. 1

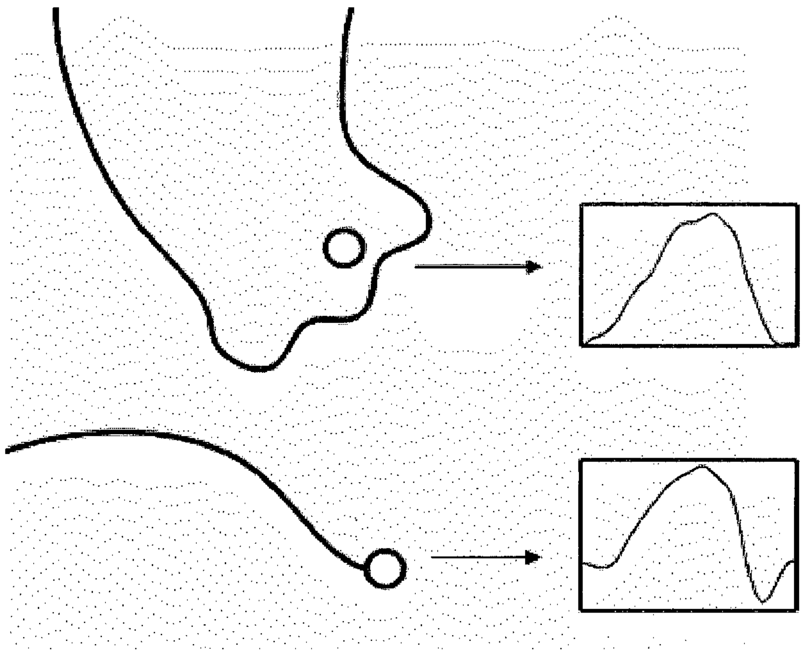

Fig. 2

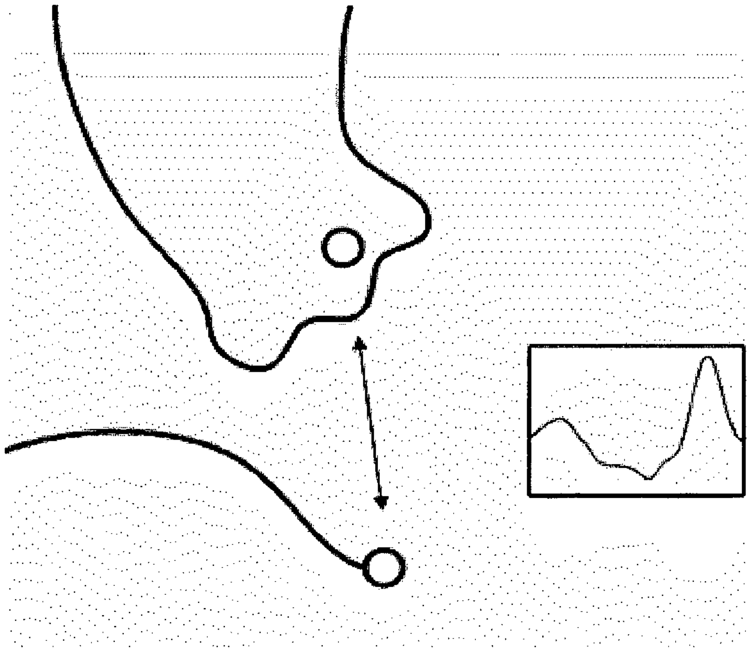

Fig. 3

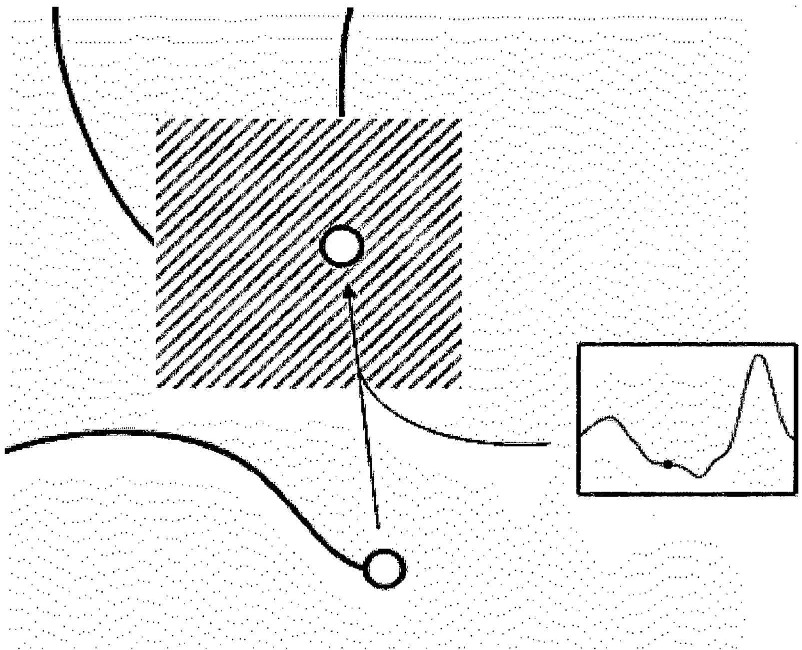

Fig. 4

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- **M. ISARD ; A. BLAKE.** Condensation - conditional density propagation for visual tracking. *International Journal of Computer Vision,* 1998 **[0005]**
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